1. What is the energy and momentum of photon of a LASER beam of wavelength 6328 Angstrom? (h= $6.6 \text{ x } 10^{-34}$JS, $C = 3 \text{ X } 10^{8}$m/s)

A. **3.128 X 10^{-19} J and 1.04 X 10^{-27} kg.m/Sec**
B. **31.28 X 10^{-19} J and 10.44 X 10^{-27} kg.m/Sec**
C. **5.65 X 10^{-16} J and 4.454 X 10^{-30} kg.m/Sec**
D. **55.128 X 10^{-16} J and 4.454 X 10^{-30} kg.m/Sec**

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D. $55.128 \text{ X } 10^{-16}$ J and $4.454 \text{ X } 10^{-30}$ kg.m/Sec

Given $\lambda = 6328 \times 10^{-10}$ m, $h = 6.63 \times 10^{-34}$ J K sec. and $c = 3 \times 10^{8}$ m/sec.

Formula used $E = h\nu = \dfrac{hc}{\lambda}$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{6.328 \times 10^{-7}\text{ m}} = 1.05 \times 10^{-19}\text{ Joule}$$

$$\cancel{E = 3.142\text{ Joule}}$$

$$\text{Momentum } p = \frac{E}{c} = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{6.328 \times 10^{-7}} = 1.05 \times 10^{-27}\text{ kg}\cdot\text{m/sec}$$

$$\cancel{p = 1.05\text{ kg}\cdot\text{m/sec.}}$$

2. What is the energy of a Ruby LASER pulse, if the wavelength of the emitted radiation and the number of Cr^{3+} ions are 6943 Angstrom and $2.8\ \mathrm{X}\ 10^{19}$ respectively?

A. 11.24 J

B. 10.69 J

C. 7.98 J

D. 5.66 J

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Calculate the energy of laser pulse in a ruby laser for 2.8×10^{19} Cr^{3+} ions. If the laser emits radiation of wavelength 6943Å.

Given: $\lambda = 6943 \times 10^{-10}$ m, $n = 2.8 \times 10^{19}$

The energy of a photon, $= h\nu$

and the total energy due to n Cr^{3+} ions is

$$E = nh\nu = n\frac{hc}{\lambda} = 2.8 \times 10^{19} \cdot \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{6.943 \times 10^{-7}}$$

$$= \mathbf{8.02\ J}$$

3. A three-level laser emits a light of wavelength of 5500 Å, What will be the ratio of population of upper level (E_2) to the lower energy level (E_1) if the optical pumping mechanism is shut off (Assume T = 300 K)?

A. 1.3 X 10^{-48}

B. 1.3 X 10^{-28}

C. 1.3 X 10^{-18}

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C. 1.3 X 10^{-18}

D. 1.3 X 10^{-38}

Given $\lambda = 5500$ Å

Formula used is

$$E_2 - E_1 = h\nu = \frac{hc}{\lambda}$$

$$= \frac{(6.63 \times 10^{-34}\,\text{J/sec}) \times (3 \times 10^{8}\,\text{m/sec})}{(5.5 \times 10^{-7}\,\text{m}) \times (1.6 \times 10^{-19}\,\text{J/eV})}$$

$$= 2.26\ \text{eV}$$

and kT can be calculated as

$$kT = (8.62 \times 10^{-5}\ \text{eV/K}) \times (300\ \text{K})$$

$$= 0.0259\ \text{eV}$$

The ratio of upper to the lower energy levels i.e.,

$$\frac{E_2}{E_1} = e^{(-E_2 - E_1)/kT} = e^{-2.26/0.0259}$$

$$= e^{-87.3}$$

$$\frac{E_2}{E_1} = \mathbf{1.3 \times 10^{-38}}$$

4. At what temperature the ratio in the previous question (Q: 3) would be 1/2?

A. 57842 K

B. 27854 K

C. 37832 K

D. 47854 K

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$$\frac{E_2}{E_1} = \frac{1}{2} = e^{-(E_2 - E_1)/kT}$$

A. 57842 K

or $$e^{(E_2 - E_1)/kT} = 2 \quad \text{or} \quad \frac{E_2 - E_1}{kT} = \log_e^2$$

B. 27854 K

or $$T = \frac{E_2 - E_1}{K \log e\, 2} = \frac{2.26 \text{ eV}}{\left(8.62 \times 10^{-5} \frac{\text{eV}}{K}\right) \times (0.693)} = 37832.75 \text{ K}$$

C. 37832 K

D. 47854 K

or $$\mathbf{T = 37832\ K}$$

This temperature is much hotter than the sun.

5. Calculate the power per unit area delivered by a laser pulse of energy $4 \text{ X } 10^{-3}$ Joule, the pulse length in time as 10^{-9} sec and when the pulse is focused on target to a very small spot of radius $1.5 \text{ X } 10^{-5}$ m.

A. $5.7 \text{ X } 10^{20} \text{ W.m}^{-2}$
B. $5.7 \text{ X } 10^{15} \text{ W.m}^{-2}$
C. $5.7 \text{ X } 10^{10} \text{ W.m}^{-2}$
D. $5.7 \text{ X } 10^{5} \text{ W.m}^{-2}$

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C. $5.7 \text{ X } 10^{10}\ \text{W.m}^{-2}$
D. $5.7 \text{ X } 10^{5}\ \text{W.m}^{-2}$

Given $P = 4.0 \times 10^{-3}$ J, $r = 1.5 \times 10^{-5}$ m

Formula used for power delivered per unit area is given by

$$I = \frac{P}{A}, \text{ where } P = \frac{4.0 \times 10^{-3}\,\text{J}}{10^{-9}\,\text{sec.}}$$

or $$P = 4.0 \times 10^{6}\ \text{W}$$

and $A = \pi r^2 = 3.14 \times (1.5 \times 10^{-5})^2 = 7.065 \times 10^{-10}\ \text{m}^2$

so $$I = \frac{P}{A} = \frac{4.0 \times 10^{6}\,\text{W}}{7.065 \times 10^{-10}\,\text{m}^2} = 5.7 \times 10^{15}\ \text{W/m}^2$$

or $$\mathbf{I = 5.7 \times 10^{15}\ W/m^2}$$